THE DIELECTRIC CONSTANT OF THE LEAD SALTS

by

M. M. Sokoloski and P. H. Fang

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland,
U.S.A.

From the mobility data of the lead salts, Allgaier and Scanlon have suggested rather large static dielectric constants, ϵ_o, of these salts[1]. Two recent works have reported ϵ_o of PbS of 140 ± 20[2] and 174.4[3] from far infrared optical transmission and reflectivity data on thin single crystal films. From microwave measurements we found ϵ_o of PbS was 161.5 ± 0.6. The experiment exploited the fact that a dielectric plate or window in a waveguide has a voltage-standing wave ratio (VSWR) minimum whenever the thickness of the plate is n half-wavelengths[4], thus

$$\epsilon_o = \left(\frac{\lambda}{nt}\right)^2 \qquad (1)$$

where t is the thickness of the crystal, λ the wavelength, and n the number of half-wavelengths traversing the sample in distance t.

Samples used in this experiment were natural crystals of PbS (Galena) from Colorado[5]. Since these crystals have conductivities of the order of 0.2 $(\Omega\text{-cm})^{-1}$, precise determination of the VSWR can be made, and at the same time,

[redacted]

no skin depth problem at 25 Gc/sec. was encountered. Table 1 gives a spectroscopic impurity analysis of the samples. Three samples were lapped or lapped and etched to thicknesses of 3.77, 3.67, and 3.25 x 10^{-2} cm., and their respective dielectric constants were 160.9, 161.3, and 162. The average value of ϵ_o, therefore, is 161.5 ± 0.6. If this value is used to calculate the transverse optical frequency, ν_t, according to the Lydane, Sachs, Teller (LST) relationship,

$$\frac{\epsilon_o}{\epsilon_o} = \left(\frac{\nu_1}{\nu_t}\right)^2 , \tag{2}$$

with ϵ = 16.8 [6], and ν_1 = 212 $cm.^{-1}$ [7], a value of ν_t = 220 $cm.^{-1}$ is obtained. This should be compared with Geick's value of 212 $cm.^{-1}$ [2] and Zemel's value of 250 $cm.^{-1}$ [3].

In the case of PbTe, there is a large discrepancy in the value of ϵ_o; Cochran has obtained a value for ϵ_o of 310 by the inelastic scattering of neutrons from single crystals [8], while Watanabe obtained a value of ϵ_o less than 200 from surface impedance measurements at 24 Gc/sec. [9]. Kanai and Shohno gave a value of 400 from the result of capacitance

[redacted]

measurements on an abrupt p-n alloyed junction [10]. However, Watanabe's experiment could have some difficulties arising from the large conductivity of PbTe. This would result in a strong attenuation of the radiation near the surface, which was experienced in our previous measurement, similar to the one described here on natural PbS, and leading to an erroneous result [11]. There is also some objection to the electrode configuration used by Kanai and Shohno. Since the results of PbS presented here show a good agreement with the result obtained from the LST relation, Cochran's result should be closer to the true value. An experiment similar to the one described here on a well compensated crystal of PbTe would be interesting.

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TABLE 1

Impurity	Percentage Detectable
Ag	0.01 - 0.1
Al	less than 0.001
Ca	" " 0.001
Cu	" " 0.001
Fe	" " 0.001
Mg	" " 0.001
Mn	" " 0.001
Sb	0.001 - 0.01
Si	0.001 - 0.01